Chapter 8

EXPLORATION DRILLING PROGRAMS

Introduction

This chapter is a guide for developing effective and efficient exploration drilling programs. Drilling programs that involve extensive soil sampling, rock coring, instrumentation installations, or in-place testing commonly have excessive cost overruns and late completion times. The effort put into developing a well organized drilling program that explicitly defines drilling and sampling requirements can lower exploration costs significantly by eliminating unnecessary or redundant work and meeting schedules. Good references on drilling methods and equipment are *Groundwater and Wells*, second edition, by Fletcher G. Driscoll, published by Johnson Division, St. Paul, Minnesota 55112, and *Drilling: The Manual of Methods, Applications, and Management*, CRC Lewis Publishers, Boca Raton, Florida, 1996.

Planning the Exploration Drilling Program

Developing an exploration program requires a thorough knowledge of the design requirements, site conditions, drilling equipment requirements and capabilities, and soil or rock core testing. It is extremely important that exploration needs be identified to avoid overdesign of a program by too many "it would be nice" requests.

A complete and detailed description of the drill site location, accessibility, work requirements, geology, and other pertinent information should be made available to either the drilling contractor or in-house drilling staff. This information is necessary for an effective and efficient drilling operation that will accomplish the program objectives. A major objective is to obtain the most information and samples possible from each hole by

optimizing location, drilling and sampling methods, depth, and completion. For example, a drill hole on the intersection of dam and outlet works centerlines drilled to the depth of the deepest data requirement and sampled for both structures provides data for both structures.

Most exploration is done in phases, with subsequent exploration designed to refine the understanding of a site. Drill holes should be logged as the holes are drilled, so hole depths and subsequent hole locations can be changed as exploration progresses. Because an exploration program evolves as data are acquired, information should be reviewed and added to maps and sections as the data become available.

Site Inspection

An onsite inspection of the drilling location should be made by the geologist, designers, and other essential members of the exploration team. The purpose of the onsite inspection is to determine the exploration needed to provide the data required for design. Data are required for several design disciplines with different needs. Having knowledgeable representatives see the site is important when formulating an exploration program. Changes and additions to exploration programs during or after exploration are expected but can be minimized with careful planning.

During the site inspection, the geologist and designers should discuss in detail all the design concerns that can only be solved by analyzing the subsurface geology. The team should be explicit as to the size, quantity, type, and quality of soil or rock samples that are necessary to develop an accurate evaluation of geologic conditions. The geologist can recommend the type of equipment and

drilling procedures needed, based on the drilling and sampling requirements, and to address design concerns as well as to provide samples needed for laboratory testing.

The onsite inspection should provide other pertinent information which is critical to the selection of specific equipment. The following factors should be addressed when preparing the exploration plan.

Topography-drill site accessibility.—The type of drilling equipment most suitable for the work needs to be determined. Truck-mounted, all-terrain, skid-mounted, or a combination of several types may be appropriate. Heavy excavation and hauling equipment may be required to construct access roads, drill pads, stream crossings, temporary bridges, or pipe culverts for river crossings. Explosives and track drills may be required to prepare drill pads or remove unsafe rock overhangs from drill sites, and roadbase or rockfill may have to be to be placed over soft mud or swamp. Helicopter support may be needed for fly-in rigs and heavy timber clearing. A source of water for drilling needs to be identified. Other considerations are whether there is a relatively close and level area that may be used as a temporary drill yard/staging area and how close equipment can be safely driven into the drill area.

Right-of-way, access permits, drilling permits, construction or clearing permits.—The drilling locations, whether on public or private land, may require access permits. Several different types of permits may be needed, including archeological and environmental permits. These permits may take considerable time to obtain and should be acquired as soon as possible. The limitations of the permits should be determined. Construction or clearing permits may be needed. Most

states require special licenses or permits for drill operators who perform water-well drilling and installation.

Protection of the Environment

Environmental, archeological, and biological factors may place restrictions or conditions on a site. Disposal of the cleared material should be arranged. The use of drilling mud requires planning and implementation prior to drilling. If the drill mud circulation pits can be excavated, the mud pits may have to be enclosed with fencing to keep out animals. Drill mud and cuttings as well as fuel and oil spills or oil change residue will require disposal. Some drill mud, cuttings, and water should be stored because the material is considered a hazardous waste. These materials may have to be disposed of at approved sites. Crossing shallow streams can create contamination or turbidity problems. Drill hole completion and site restoration should be formulated. Dust abatement may be necessary for travel over the access roads. Routes through planted fields should be arranged before travel.

Drilling

Many factors should be considered during the development of the exploration plan as listed below:

- Are the drill sites on rock
- Can downhole hammers be used to set collar casing
- Are surficial materials suitable for hollow-stem auger use
- If the drill hole is to be water-pressure tested, may drilling mud or air foam be used

- Are soil samples required
- Can casing or hollow-stem augers be advanced through the surficial deposits so that rock coring can be performed
- Can the drill hole be used to combine geophysical and in-place testing
- Will geophysical testing be required in the drill hole
- Are angle holes required
- Will the holes require directional drilling control and then be verified by survey
- Will polyvinyl chloride (PVC) casing have to be installed for survey confirmation
- Will water pressure tests or permeability tests be required as the hole is drilled or can the testing be performed after the hole is completed
- Will the permeability tests require packers and pressure testing or gravity head pressure
- Will the holes require instrumentation installation
- What are the requirements for the backfill in the instrumentation drill hole and how is it to be placed
- Will the outside annulus of the casing require grouting
- What are the hole completion requirements

Equipment

- Are the requirements for soil sample and/or rock core sizes compatible with existing commercially available equipment
- Will the samples or cores have to be transmitted to the testing laboratories in sealed liners, split tube liners, thin-wall steel tubes, or cheesecloth and wax seals in core boxes
- Are there special concerns for the samples and their delivery
- Will those concerns require them to be transported in vibration-free containers
- Should the samples be protected from freezing
- Should the samples be weighed in the field and the density and moisture content determined before delivery to the laboratories
- What is the minimum drill equipment that should be specified considering the total hole depth, size of core or soil sample requirements, borehole diameter, and rod size
- What is the minimum mud pump or air compressor rating that should be specified
- Where is the water source; will water have to be hauled or can it be pumped to the drill site
- How much water line will have to be laid

Traffic Control and Safety

- Will the drill locations require traffic control, detours, barricades, flag personnel, etc., for safety and public protection
- Will road or highway travel require rerouting during the drilling program
- Has permission been obtained from local, county, or state officials to close roads
- Will drilling be performed in high visibility areas
- Will equipment security and vandalism be enough of a problem to warrant nighttime security personnel or fencing

Special Considerations

- Will the drilling require excavating or constructing ramps and drill pads on the slope face of an earth embankment
- Will the embankment slope face drilling have to be done with skid-rigs on timber cribbing platforms or with specialized drills that are capable of traversing and drilling into embankment slope faces without excavating ramps or benches
- Will underground drilling be required
- Establish and include all underground safety requirements in the drilling specifications
- Size the underground drilling equipment so it will be suitable for the height and width of the tunnel or drift

- Is there potential for large water inflows
- Is there potential to intercept reservoir water during underground drilling operations
- Will the drilling program require drill setups on scaffolds or hanging platforms
- Are qualified personnel available to review the design of any scaffold or hanging platform drill setup, and will they have the authority to accept or reject the construction
- Will the drilling program require operation from a floating plant (barge) or a jack-up platform
- Obtain data for fluctuating river rises or falls, flow rate, and depth of water under normal flow conditions
- Will drilling be required in the vicinity of overhead transmission lines, transformer boxes, or underground buried utilities
- Have all underground utilities been located and flagged
- Will the program require helicopter service for fly-in rigs
- Have fly-in hazards been identified prior to start, such as transmission lines, heavy timber, turbulent winds, and rough terrain
- Are artesian pressures anticipated
- Are circulation loss zones anticipated
- Have contingency plans been prepared to seal and contain artesian water flow or large volume water flow that may be encountered during any drilling operations

- Has it been determined how the drill holes are to be completed, i.e., capped and locked collar casing, collar casing guard fixtures, or install piezometers or other monitoring instrumentation, or backfilled and grouted

Drilling in Dam Embankments

The Bureau of Reclamation's (Reclamation) embankment design practice minimizes development of stress patterns within an embankment. Stress patterns could lead to hydraulic fracturing by drill fluids during drilling. Certain embankment locations and conditions have a higher potential for hydraulic fracturing than others, and improper drilling procedures or methods will increase the potential for hydraulic fracturing. Site locations and conditions where hydraulic fracturing by drilling media are more likely to occur and adversely affect a structure's performance include the following:

1. In impervious cores with slopes steeper than 0.5H:1V, cut-off trenches, and upstream-inclined cores.

2. Near abutments steeper than 0.5H:1V, where abrupt changes in slopes occur, and above boundaries in the foundation which sharply separate areas of contrasting compressibility.

3. Near structures within embankments.

4. In impervious zones consisting of silt or mixtures of fine sand and silt.

Recommended procedures for developing exploration and instrumentation programs and for drilling in the impervious portion of embankment dams are as follows:

1. The embankment design should indicate whether a hydraulic fracturing potential exists.

2. If a high potential for hydrofracturing exists, the type of equipment and the method and technique to be used for drilling must have the approval of the exploration team. Once drilling has commenced, drilling personnel are responsible for controlling and monitoring drill media pressure, drill media circulation loss, and penetration rate to assure that the drilling operation minimizes the possibility for hydraulic fracturing.

3. If a sudden loss of drill fluid occurs during any embankment drilling within the dam core, drilling should be stopped immediately. Action should be taken to stop the loss of drill fluid. The reason for loss should be determined, and if hydraulic fracturing may have been the reason for the fluid loss, the geologist and designer should be notified.

With the exception of augering, any drilling method has the potential to hydraulically fracture an embankment if care is not taken and attention is not paid to detail. Augering is the preferred method of drilling in the core of embankment dams. Augering does not pressurize the embankment, and no potential for hydrofracturing exists. Use of a hollow-stem auger permits sampling in the embankment and allows sampling/testing of the founda-tion through the auger's hollow stem, which acts as casing.

Drilling methods which may be approved for drilling in embankment dams if augering is not practical (i.e., cobbly fill) are as follows:

1. Cable tool
2. Direct rotary with mud (bentonite or biodegradable)
3. Direct rotary with water
4. Direct rotary with air-foam
5. Down-hole hammer with reverse circulation

Selection of any one of the above methods should be based on site-specific conditions, hole utilization, economic considerations, and availability of equipment and trained personnel.

Any drilling into the impervious core of an embankment dam should be performed by experienced drill crews that employ methods and procedures that minimize the potential for hydraulic fracturing. It is essential that drillers be well trained and aware of the causes of and the problems resulting from hydraulic fracturing.

Safety

Drilling safety requirements and safety requirements in general are available in *Reclamation Safety and Health Standards*, Bureau of Reclamation, United States Department of Interior, 1993.

Preparation of Drilling Specifications and Format

The work requirements should be compiled in a clear and concise manner for use by the personnel who will

perform and inspect the work. The following is a suggested specifications format for drilling contracts.

a. General Description of Exploration Program

(1) Available Geologic Data

(2) Identification of Design Concerns

(3) Generalized Exploration Drilling, Coring, Testing, Instrumentation Requirements

b. Location of Work

(1) Area Identification

(2) Nearest Community

(3) Emergency Facilities

(4) Nearest Living Quarters/Crew Camp Area

(5) Freight Facilities

(6) Fuel and Supply Business Locations

(7) Travel Routes/Road Restrictions

(8) Public/Private Land Access Routes/Restrictions

(9) Right-of-Way Permits

c. Site Location

(1) Hole Locations

(2) Topography/Accessibility

(3) Protection of the Environment

(4) Water Source

(5) Waste Disposal Area/Acceptable Waste Disposal Method

(6) Drill Yard Storage Area—Restrictions

d. Work Requirements

(1) Site Preparation

(2) Collaring Holes—Boring Size—Angle

(3) Casing Requirements

(4) Sample Requirements (Disturbed/Undisturbed)

(5) Sample Sizes and Intervals

(6) Care and Transportation of Samples

(7) Core Sizes and Intervals

(8) Care and Preservation of Rock Core

(9) In-Place Testing Requirements

(10) Instrumentation Requirements

(11) Hole Backfill and Completion

(12) Site Cleanup

e. Equipment Requirements

(1) Drill Rig Capabilities

(2) Pump/Air Compressor Capabilities

(3) Drilling Media

(4) Sampling/Coring Equipment

(5) In Situ Testing Equipment

(6) Instrumentation Equipment

(7) Core Boxes/Sample Containers

f. Special Drilling Concerns

g. Potential for Program Change, Modification, or Extension

h. Safety Program/Safety Requirements/Safety Contingency Plans

i. Exploration Drilling Reports and Logs

j. Labor Checks/Equipment Checks/Cost Accounting